DISTRIBUTION OF MAGNETITE, CARBONATES, ILLITE, KAOLINITE/CHLORITE, QUARTZ, AND FELDSPARS IN GRAIN SIZE FRACTIONS OF THE WISCONSIN AGE GAHANNA DRIFT, GAHANNA, OHIO

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ABSTRACT

Removal of magnetite, from suspended clay size till and from coarse till grains, with a hand held magnet was used to determine the concentration and distribution of magnetite in mesh size fractions of three tills at Gahanna, Ohio. Concentration and distribution of magnetite may be used to characterize till layers and correlate them regionally. Carbonate concentration and distribution were determined by leaching with 2N HCl. X-ray diffraction data for illite, kaolinite/chlorite, quartz, and feldspar was used to further characterize lithologies of the three tills. Distribution of magnetite, illite, and kaolinite/chlorite in grain sizes was used to confirm the lack of weathering in the Gahanna, Ohio tills.

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INTRODUCTION

Ohio tills have been studied using a variety of quantitative methods. In particular, radiocarbon dates (Goldthwait, 1965), feldspar provenance determinations (Taylor and Faure, 1982), and paleomagnetics (Choate, 1980) have been used for analysis of Wisconsin-aged tills found in Gahanna, Ohio, along the Rocky Fork Creek (Figure 1). New methods of till analysis are still being sought.

The objectives of this study are:

1) To initiate the use of magnetite concentrations in tills for distinguishing till layers and for regional correlation of tills.
2) To characterize the lithology of the Gahanna till layers using data on magnetite and carbonate concentrations and x-ray diffraction data on illite, kaolinite/chlorite, quartz, and feldspars.

The Gahanna tills were deposited by the Scioto Sublobe of the Huron Lobe or by a combination of the Huron-Georgian Bay and Erie lobes (Dreimanis and Goldthwait, 1973). Source areas for the glacial lobes are: Huron Lobe, Superior-Southern Province; Georgian Bay Lobe, western Grenville Province; and the Erie Lobe, also from the western Grenville Province (Gwyn and Dreimanis, 1979) (Figure 2). The exposure contains three till layers overlying the red Mississippian Bedford Shale. In ascending order, they are: The Rocky Fork till, the Middle Blue till,

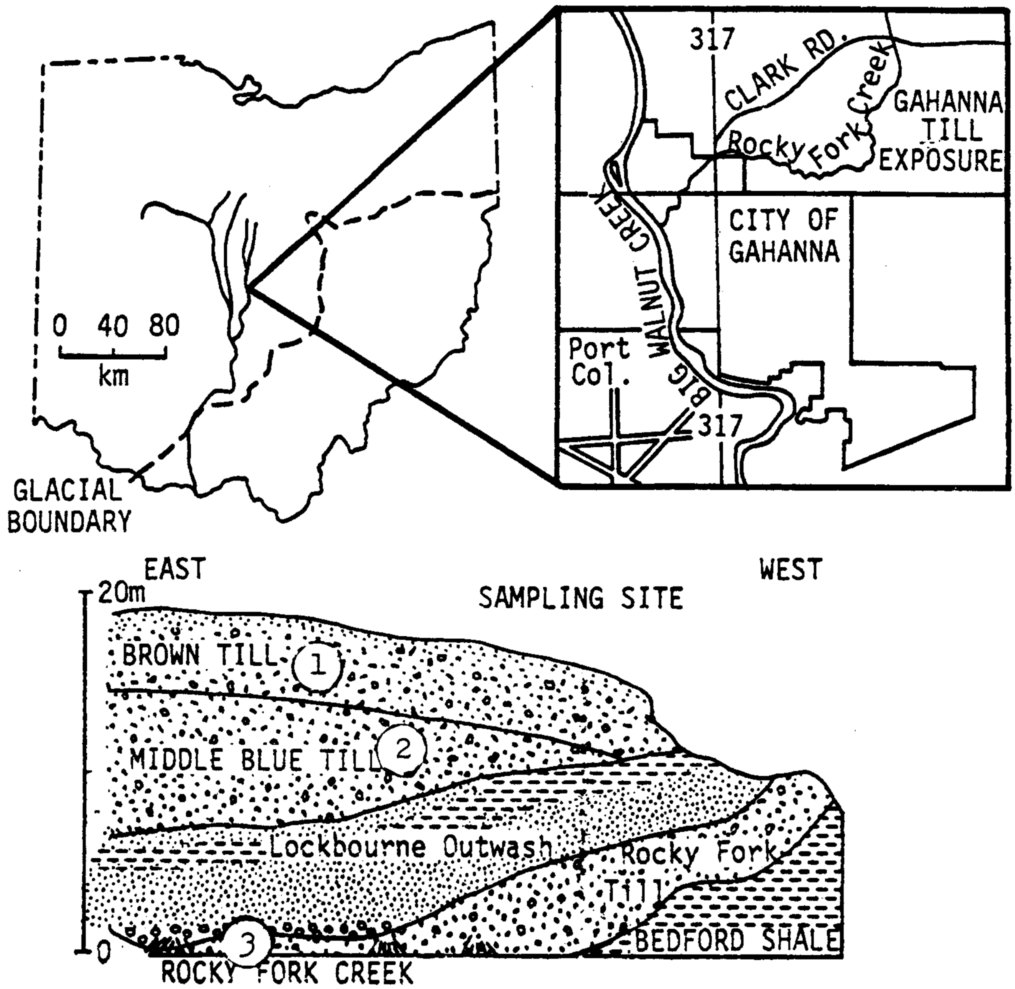

Figure 1. Location of collecting site and stratigraphic section of till and outwash deposits on the Rocky Fork Creek in Gahanna, Ohio (Goldthwait, 1965).

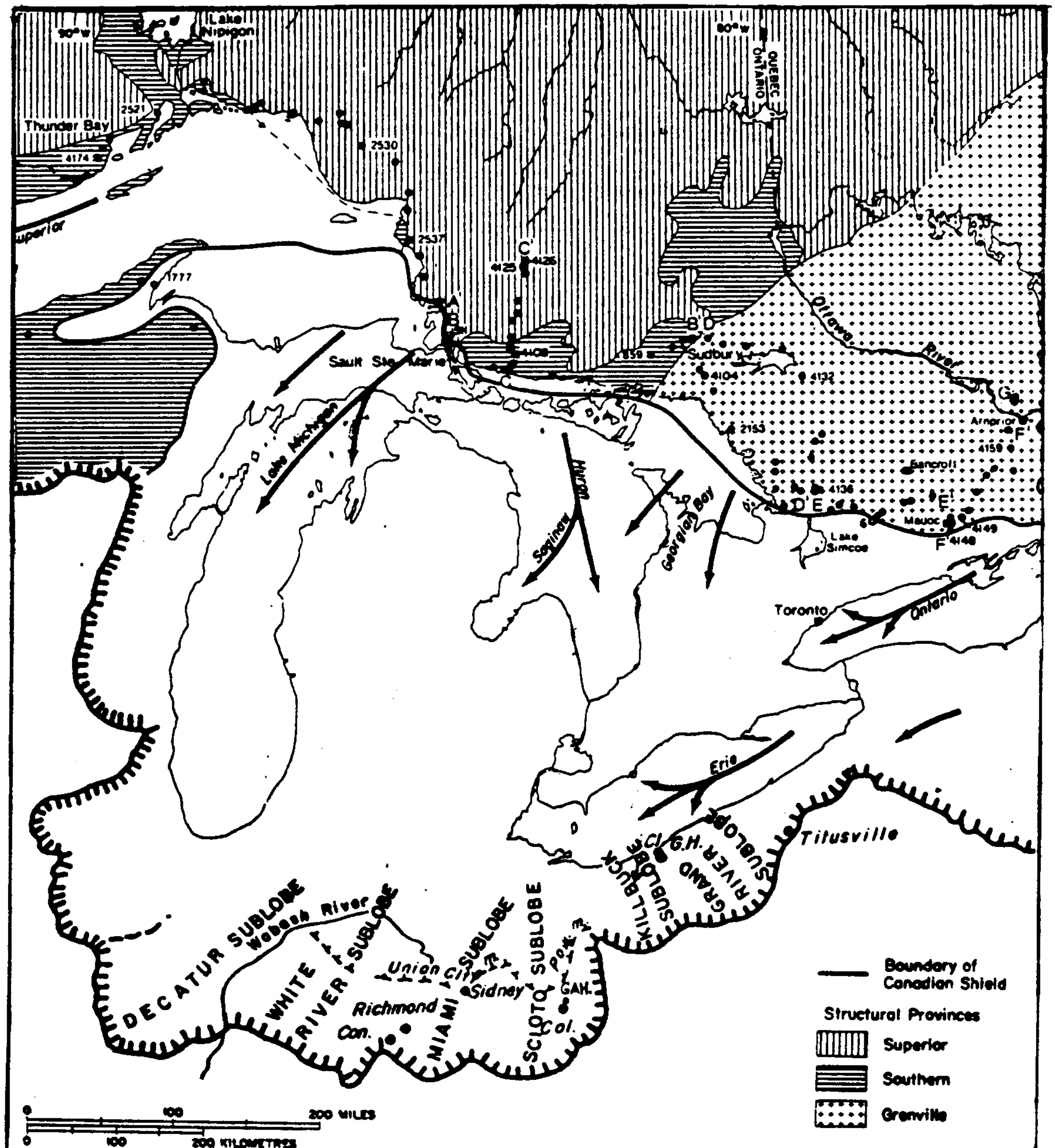

Figure 2. Distribution of glacial lobes and sublobes. Arrows indicate glacial movements (Dreimanis and Goldthwait, 1972). Outline of structural provinces in the Canadian Shield in the Great Lakes region (Gwyn and Dreimanis, 1979).

and the Upper Brown till. The Rocky Fork till and the Lockbourne Outwash that overlies it have an early Wisconsin (Altonian) age, radiocarbon date 46,600 ± 2000 B.P., the Middle Blue till has a late Wisconsin (Shelbyville) age, 23,000 ± 850 B.P., and the Upper Brown till has a late Wisconsin (Bloomington ?) age (Goldthwait, 1965).

At the sampling site in Gahanna (Figure 1, Plates 1 and 2), the Rocky Fork till is blue gray in color, clay rich, and well compacted. The Middle Blue till is dark gray, contains less clasts than the Rocky Fork till, and is well compacted. It also contains sandy lenses and wood fragments near its base probably derived from the underlying Lockbourne Outwash (Taylor and Faure, 1982). The Upper Brown till is light brown and less compacted than the lower two till layers (Plates 3-5).

ANALYTICAL PROCEDURES

One sample weighting approximately 3 kg was collected from each till layer. Each sample was soaked in water to break down the compacted material. The suspended clay size fraction from each till sample was decanted through a -250 mesh sieve. Magnetite was removed from these -250 size fractions by placing a magnet in a plastic bag and repeatedly lowering it into the suspended material. The -250 mesh magnetite for each till layer was washed into beakers and dried. The remaining coarse fraction from each till layer was dried under a heat lamp and sieved into +5, -5+10, -10+18, -18+35, -35+60, -60+120, -120+250, and -250 mesh size fractions. A hand held magnet was repeatedly run over each size fraction to remove magnetite. It is important to note

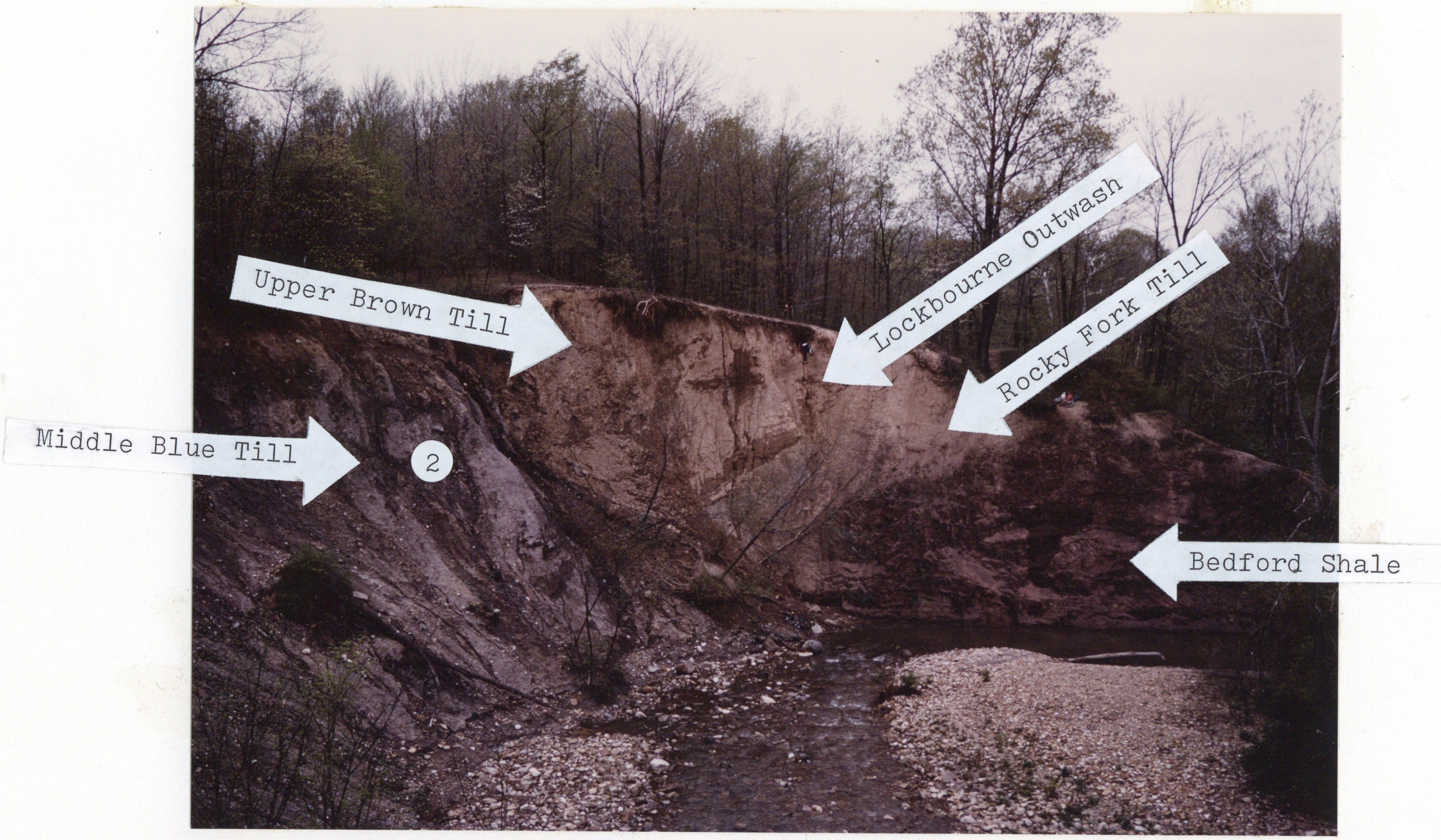

Plate 1. Sample locations and relation of Gahanna tills to Bedford Shale.

Plate 2. Sample locations and relation of Gahanna, Ohio tills to Lockbourne Outwash.

Plate 3. Upper Brown till at Gahanna, Ohio.

Plate 4. Middle Blue till at Gahanna, Ohio.

Plate 5. Rocky Fork till at Gahanna, Ohio.

that the use of this procedure does not suggest there were magnetite grains as coarse as +5 mesh, for example, but that a certain amount of magnetite was recovered from the +5 mesh size fraction. The resultant magnetite samples were purified by crushing them in an agate mortar and further combing them with the magnet. Magnetite derived from the suspended clay-size fractions was combined with the -250 mesh magnetite derived from sieving. The pure magnetite from each size fraction of each till layer was weighed on an analytical balance (Table 1). Remaining till size fractions were weighed on a triple balance (Table 2).

Carbonate concentrations were determined for all size fractions except the +5. Carbonates were removed from the till by leaching with 2N HCl. Each size fraction was weighed and the weights of the carbonate minerals were determined by difference (Table 3).

A sample of each size fraction, except the +5, was ground to 200 mesh and mounted on glass slides for x-ray diffraction. Each slide was scanned for illite, kaolinite/chlorite, quartz, and feldspar with 2θ angles of 8.84°, 12.34°, 26.66°, and 27.5° K-feldspar/28.0° plagioclase, respectively. A Cu target was used; settings were 45KVP and 15 ma. Due to the unoriented nature of the mixture, each slide was scanned first with a forward goniometer arc, then rotated, and scanned with a reverse goniometer arc. This resulted in a plot of diffraction angles vs. two peak intensities of diffracted radiation for each mineral. The two peak heights for each mineral were averaged for each slide to determine relative concentrations (Table 4).

Table 1. Weight of magnetite, in mesh size fractions, derived from samples (2.5kg - 3kg) of till at Gahanna, Ohio.

Size Fraction	Upper Brown Till (g)	Middle Blue Till (g)	Rocky Fork Till (g)
+5	.0382	-	.0857
-5+10	.0674	.1114	.0613
-10+18	.0424	.0944	.0993
-18+35	.0521	.0841	.2067
-35+60	.0737	.2099	.2908
-60+120	.2710	.4213	.4147
-120+250	.3449	.3240	.2337
-250	.2766	1.070	.5037

Table 2. Weight and weight percent of till, in mesh size fractions, derived from samples (2.5kg - 3kg) at Gahanna, Ohio.

Size Fraction	Upper Brown Till		Middle Blue Till		Rocky Fork Till	
	(g)	%	(g)	%	(g)	%
+5	276.3	10.64	419.2	15.52	368.2	12.57
-5+10	150.0	5.779	142.1	5.261	197.3	6.735
-10+18	122.7	4.727	132.3	4.898	238.6	8.144
-18+35	116.1	4.473	127.5	4.721	210.0	7.168
-35+60	105.7	4.072	117.3	4.343	253.5	8.653
-60+120	175.0	6.742	212.3	7.861	218.0	7.441
-120+250	235.6	9.077	119.3	4.417	134.7	4.598
-250	1414.2	54.484	1430.7	52.973	1309.3	44.692

Table 3. Weight of carbonate minerals, in mesh size fractions, derived from samples (2.5kg - 3kg) of till at Gahanna, Ohio.

Size Fraction	Upper Brown Till (g)	Middle Blue Till (g)	Rocky Fork Till (g)
-5+10	38.5	37.5	55.8
-10+18	27.3	36.3	88.3
-18+35	19.9	29.5	62.7
-35+60	15.7	20.7	83.0
-60+120	16.9	22.4	52.9
-120+250	16.7	13.5	42.9
-250	164.2	204.2	86.2

Table 4. Relative abundance of illite, kaolinite/chlorite, quartz, and feldspar in mesh size fractions of till at Gahanna, Ohio.

Size Fraction	Upper Brown Till	Middle Blue Till	Rocky Fork Till
	Illite (%)		
-5+10	10.5	16.9	12.5
-10+18	17.5	27.1	20.3
-18+35	18.6	21.1	21.8
-35+60	17.9	21.2	13.6
-60+120	13.6	9.04	10.1
-120+250	8.70	-	10.1
-250	13.1	3.61	11.5
	Kaolinite/Chlorite (%)		
-5+10	21.8	27.0	18.7
-10+18	17.9	18.0	23.5
-18+35	23.9	26.0	24.9
-35+60	11.6	21.0	11.5
-60+120	15.0	-	-
-120+250	9.70	-	5.30
-250	-	8.00	16.0
	Quartz (%)		
-5+10	13.1	15.1	9.90
-10+18	10.7	7.43	8.30
-18+35	10.8	10.8	11.1
-35+60	9.90	14.9	14.6
-60+120	15.5	15.7	21.3
-120+250	19.5	19.9	23.2
-250	20.4	15.9	11.5
	Feldspar (%)		
-5+10	13.5	16.1	6.50
-10+18	9.20	3.98	13.4
-18+35	14.3	11.9	10.3
-35+60	17.7	17.6	21.4
-60+120	6.90	13.6	20.3
-120+250	11.9	14.6	17.1
-250	26.4	22.2	10.9

RESULTS

Grain size distribution by weight percent for each of the Rocky Fork, Middle Blue, and Upper Brown till layers is illustrated in the histograms of Figure 3. The +5 mesh and the -250 mesh size fractions lack upper or lower bounds and should be interpreted accordingly.

The Upper Brown till has a bimodal grain size distribution. It contains 10% +5 mesh and 54% -250 mesh material. Of the three layers, the Upper Brown till characteristically contains the largest amount of fine material with 62% of the till -60 mesh. The Middle Blue till also has a bimodal grain size distribution. It contains slightly more coarse material, 15% +5 mesh, and slightly less fine material, 52% -250 mesh, than the Upper Brown. A small peak at -60+120 mesh is present. The Rocky Fork till has a histogram which illustrates its coarser make up with on 44% of the till layer -250 mesh.

DISTRIBUTION OF MAGNETITE

Three different aspects of magnetite distribution were analyzed (Table 5).

The total amount of magnetite in the Upper Brown, Middle Blue, and Rocky Fork tills is indicated as a weight percent of each till layer respectively in Figure 4. The Middle Blue till has the greatest concentration of magnetite (.085%), while the Upper Brown till has .05% magnetite, and the Rocky Fork till contains .06% magnetite.

The histograms of Figure 5 compare the relative amounts of magnetite derived from each grain size within each till layer.

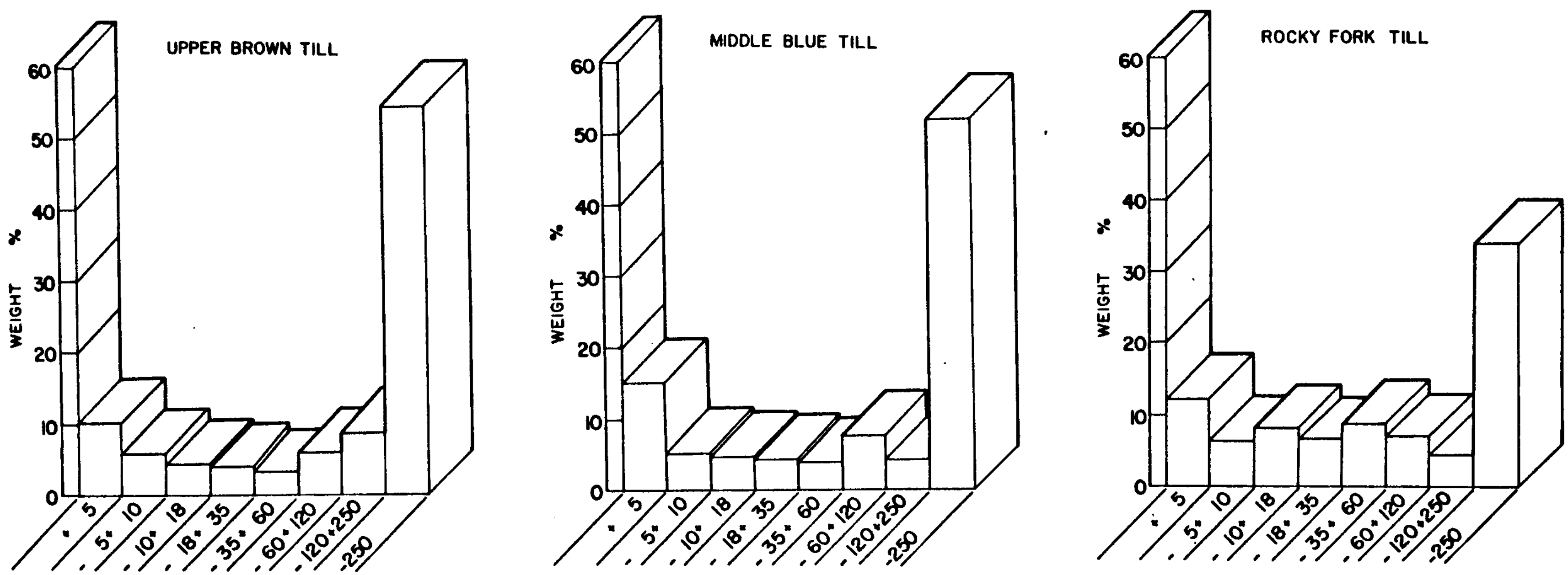

Figure 3. Histograms of grain size distribution of tills by weight percent at Gahanna, Ohio.

Table 5. a) Percent concentration of magnetite in till layers at Gahanna, Ohio. b) Relative abundance of magnetite and c) percent concentration of magnetite in each size fraction of these tills.

a)

	Upper Brown Till	Middle Blue Till	Rocky Fork Till
	.0449%	.0857%	.0647%

b)

Size Fraction	Upper Brown Till %	Middle Blue Till %	Rocky Fork Till %
+5	3.27	-	4.52
-5+10	5.78	4.81	3.23
-10+18	3.63	4.07	5.24
-18+35	4.47	3.63	10.9
-35+60	6.32	9.07	15.3
-60+120	23.2	18.2	21.9
-120+250	29.6	14.0	12.3
-250	23.7	46.2	26.6

c)

Size Fraction	Upper Brown Till %	Middle Blue Till %	Rocky Fork Till %
+5	.0138	-	.0233
-5+10	.0449	.0791	.0312
-10+18	.0345	.0719	.0416
-18+35	.0449	.0665	.0984
-35+60	.0697	.1808	.1147
-60+120	.1548	.1999	.1902
-120+250	.1464	.2734	.1735
-250	.0195	.0748	.0764

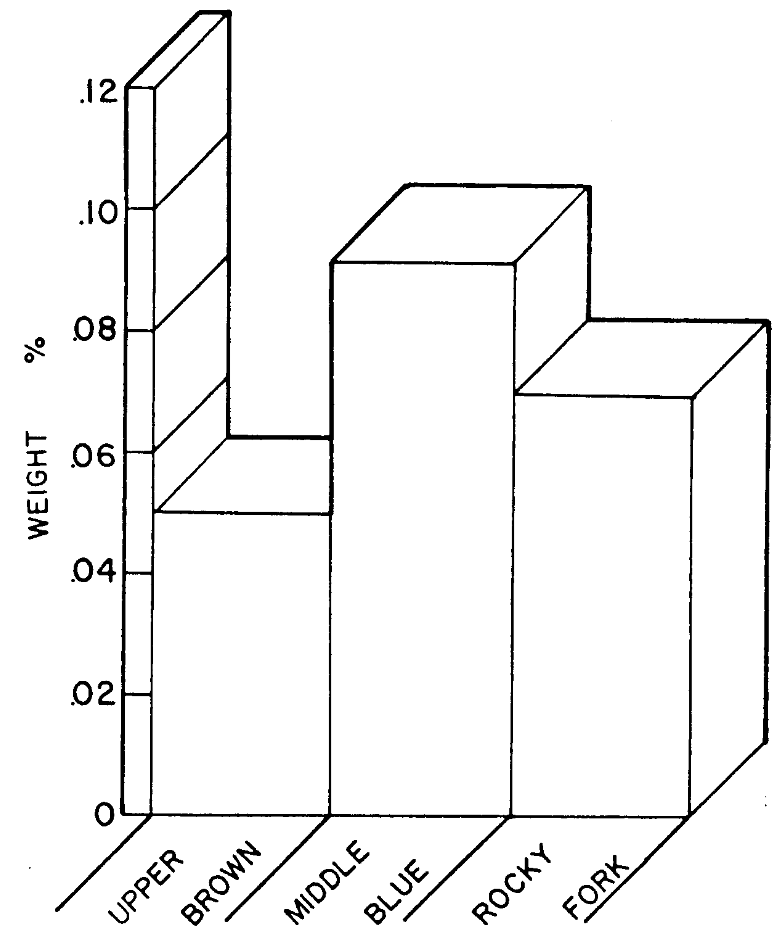

Figure 4. Percent concentration of magnetite in each till layer at Gahanna, Ohio.

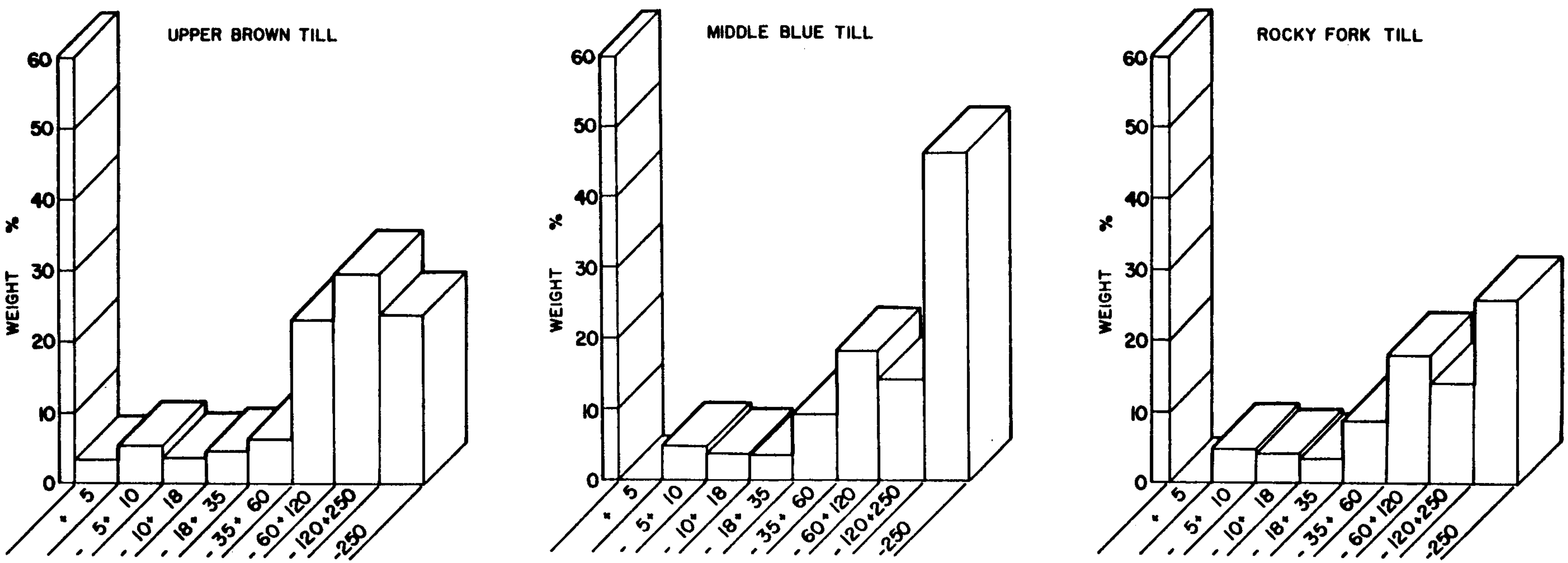

Figure 5. Relative percent of total magnetite of each till layer in each size fraction at Gahanna, Ohio.

In all three till layers, most of the magnetite recovered was derived from the -60 mesh fraction. Peaks of maximum magnetite concentration: Upper Brown, approximately 30% magnetite in the -120+250 mesh; Middle Blue, approximately 45% in the -250 mesh, and Rocky Fork, approximately 25% in the -250 mesh. Using the method of running a hand held magnet over the different grain sizes of till to obtain magnetite, it is possible that small grains of magnetite in the coarse grains were not recovered. However, since the grains containing magnetite were crushed and subsequently combed with a magnet, the weight percents used in the histograms reflect the weight distribution of pure magnetite.

Finally, the concentration of magnetite in each size fraction of each till layer is illustrated by weight percent in Figure 6. The Upper Brown till contains less magnetite in each size fraction than the other two till layers. Magnetite concentration in the Upper Brown peaks at .07% in the -35+60 mesh. Any Upper Brown till finer than this concentrates much less magnetite. Magnetite concentration peaks at .27% in the -20+250 mesh of the Middle Blue till. Although the -250 mesh size fraction of the Middle Blue till contains far more magnetite by weight than the other size fractions, the concentration of magnetite in the -250 mesh is markedly less than the concentration in the -120+250 mesh. The fine size fractions of the Rocky Fork till have the greatest concentration of magnetite in this layer. The magnetite in the -250 mesh, however, is not significantly less than the -120+250 mesh magnetite as it is in the Middle Blue till.

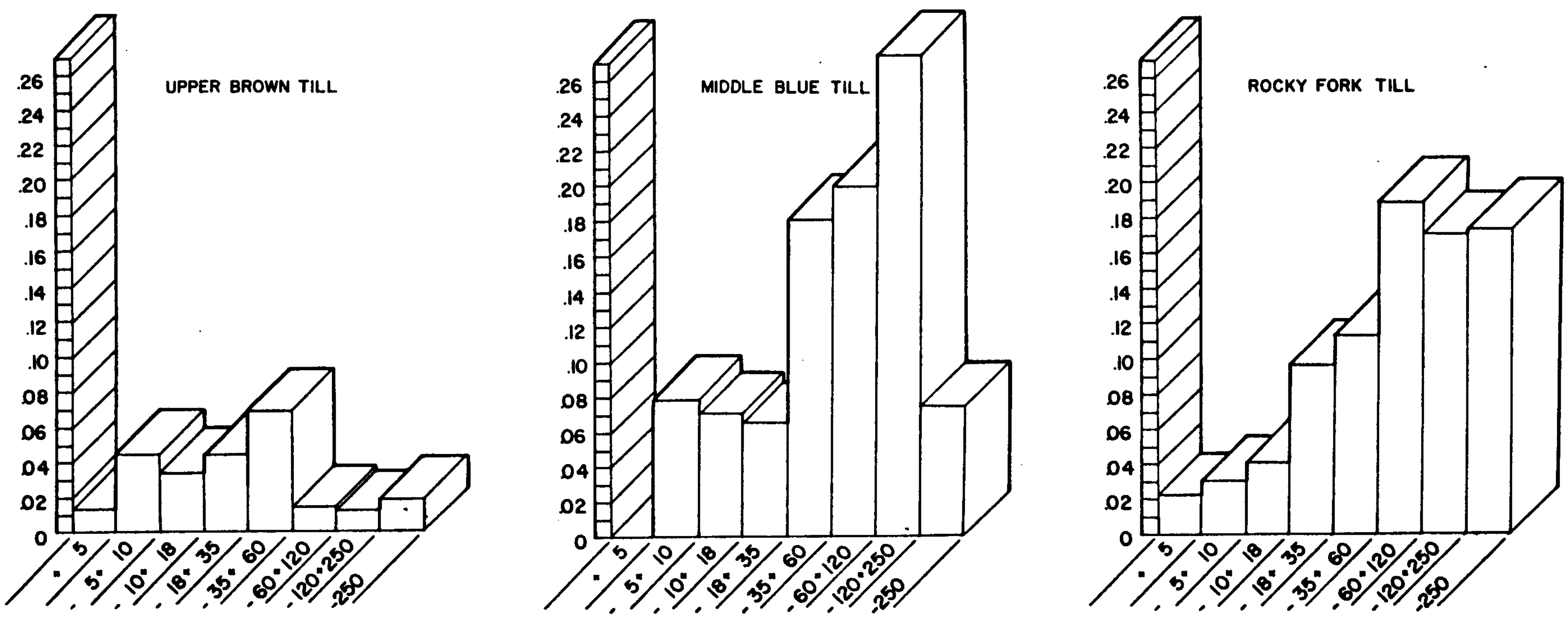

Figure 6. Histograms illustrating concentration of magnetite by weight percent in each size fraction of each till layer at Gahanna, Ohio.

DISTRIBUTION OF CARBONATES

The three methods used to analyze magnetite distribution were also used to analyze carbonate distribution (Table 6).

A comparison of the total amount of carbonates by weight percent in the Upper Brown till, the Middle Blue till, and the Rocky Fork till is found in Figure 7. Going down section, concentration of carbonate minerals increases: 12.9% in the Upper Brown, 16.2% in the Middle Blue, and 18.4% in the Rocky Fork.

The histograms of Figure 8 compare the relative distribution of carbonates by grain size in each till layer. The distribution of carbonates in the Upper Brown till and the Middle Blue till is very similar, with slightly more than 50% of the carbonate minerals -250 mesh. Both are also slightly bimodal (decrease from -5 to +250 mesh) with > 10% of the till -5+10 mesh. The Rocky Fork till has nearly an even distribution of carbonates.

The concentration of carbonates in each size fraction of each till layer is illustrated in Figure 9 . In the Upper Brown till layer the -5+10 mesh size fraction is composed of 25% carbonates. The concentration of carbonates gradually decreases to the +250 mesh. The -250 mesh increases to 11%. The Middle Blue till exhibits a similar decrease to the -60+120 mesh fraction (approximately 10% carbonates). Till less than 120 mesh exhibits a slight increase (14% carbonates). The till of the Rocky Fork layer has the greatest concentration of carbonate minerals (approximately 25% - 35%) in all size fractions, except the -250

Table 6. a) Percent concentration of carbonates in till layers at Gahanna, Ohio. b) Relative abundance of carbonates and c) percent concentration of carbonates in each size fraction of these tills.

a)

Upper Brown Till	Middle Blue Till	Rocky Fork Till
12.9%	16.3%	18.4%

b)

Size Fraction	Upper Brown Till	Middle Blue Till	Rocky Fork Till
	%	%	%
-5+10	12.8	10.3	11.8
-10+18	9.12	9.97	18.7
-18+35	6.65	8.10	13.3
-35+60	5.25	5.68	17.6
-60+120	5.65	6.15	11.2
-120+250	5.58	3.71	9.09
+250	54.8	56.1	18.3

c)

Size Fraction	Upper Brown Till	Middle Blue Till	Rocky Fork Till
	%	%	%
-5+10	25.6	26.6	28.3
-10+18	22.2	27.6	37.0
-18+35	17.1	23.3	29.9
-35+60	14.8	17.8	32.7
-60+120	9.66	10.6	24.3
-120+250	7.09	11.4	31.8
-250	11.6	14.3	6.59

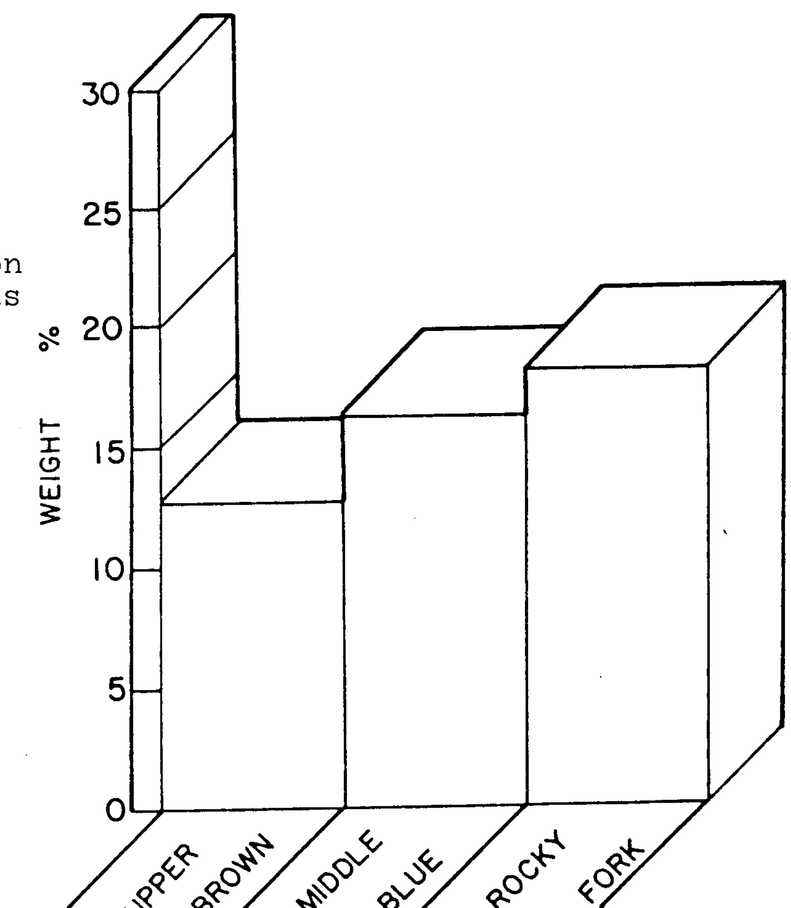

Figure 7. Percent concentration of carbonate minerals in each till layer at Gahanna, Ohio.

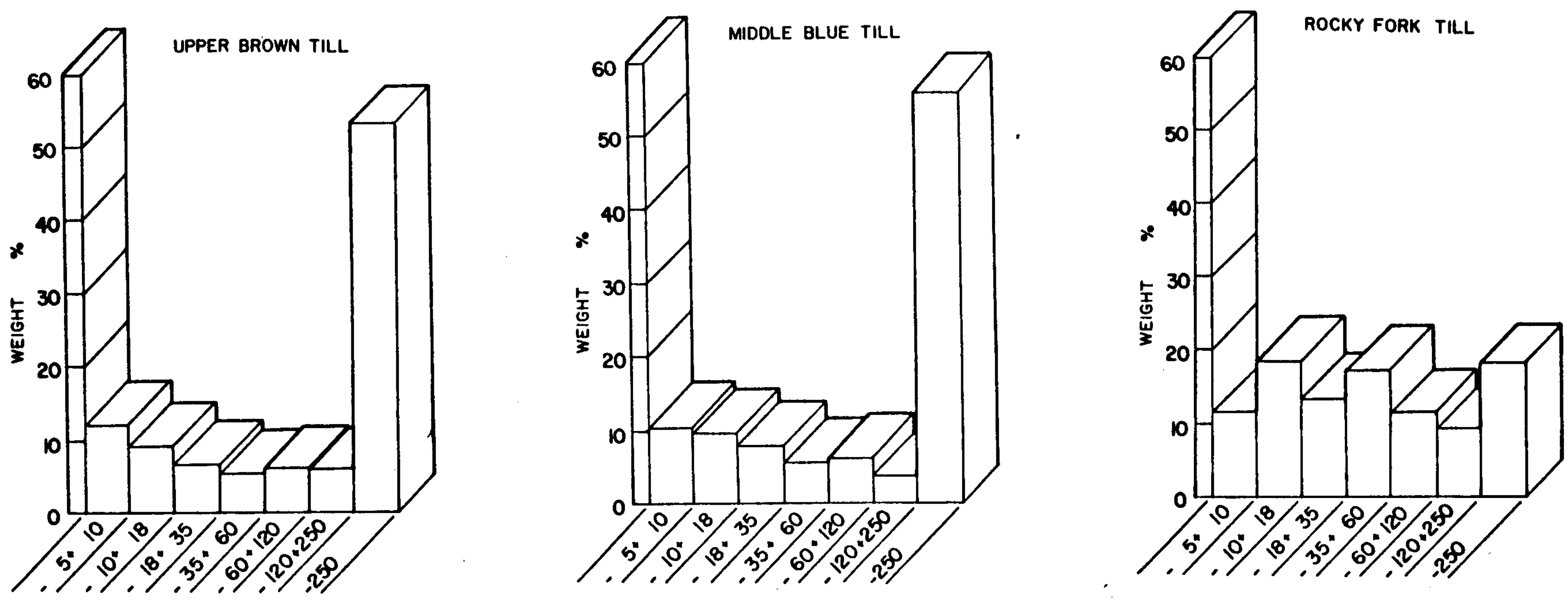

Figure 8. Histograms of relative percent of total carbonates of each till layer in each size fraction at Gahanna, Ohio.

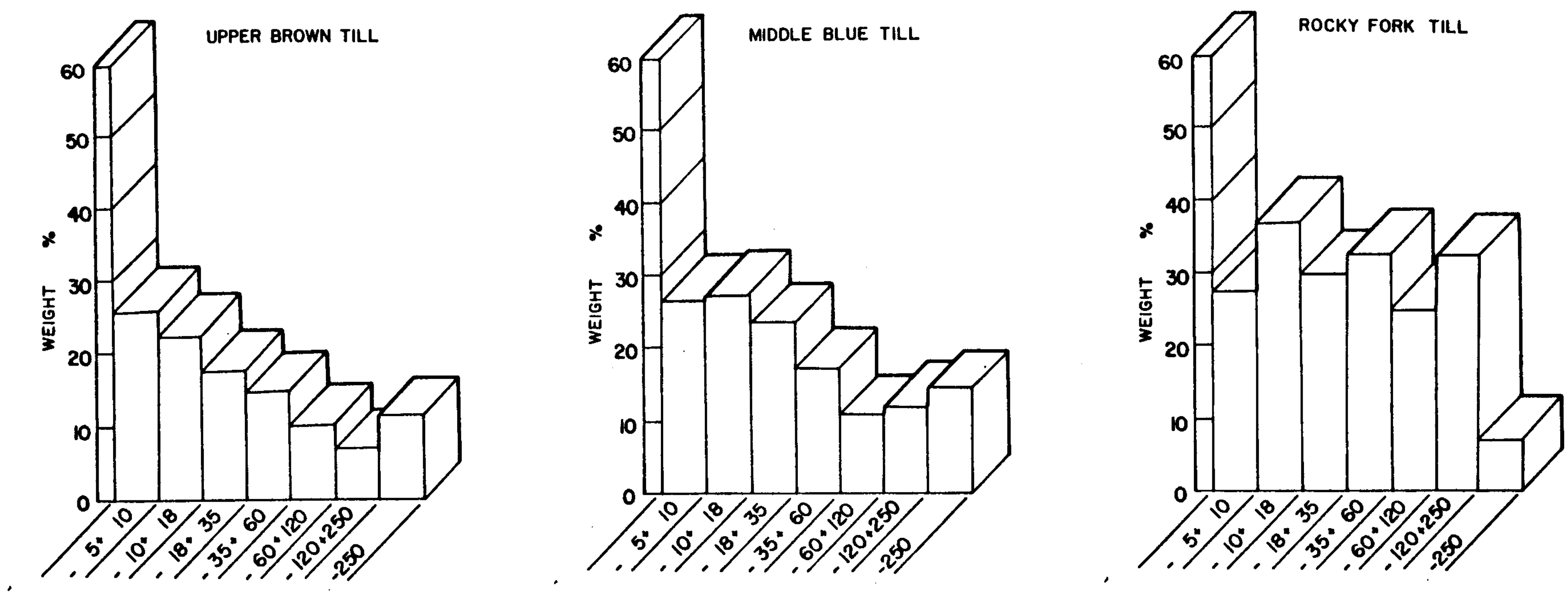

Figure 9. Concentration of carbonate minerals in each size fraction of each till layer at Gahanna, Ohio.

mesh, which contains only 6% carbonate minerals by weight percent.

DISTRIBUTION OF ILLITE, KAOLINITE/CHLORITE, QUARTZ AND FELDSPAR AS DETERMINED BY X-RAY DIFFRACTION

Relative percent abundances of illite, kaolinite/chlorite, quartz, and feldspar were determined for each of the three till layers. Distribution of each mineral by size fraction was determined by averaging peak intensities from two x-ray runs.

The greatest amount of illite for all three till layers was found in the size range -5 mesh to +60 mesh. The three till layers exhibit a bimodal distribution of illite; the illite in the coarse fractions is probably derived from shale clasts while the fine grained illite indicates the occurrence of illite clay. (Figure 10).

The kaolinite/chlorite analysis resulted in a bimodal distribution, probably reflecting the occurrence of kaolinite/chlorite (possibly even mica) incorporated in coarse grains versus kaolinite clay in the fine fractions. The size fractions between -5 and +250 mesh of the Upper Brown till each contain from 10% to 25% of the kaolinite/chlorite in the till layer. No kaolinite/chlorite was found in the -250 mesh fraction. The size fractions between -5+60 mesh of the Middle Blue till each contain 18% - 28% of the kaolinite/chlorite present. No kaolinite or chlorite was found in -60 to +250 mesh. Till -250 mesh contains roughly 8% of the kaolinite/chlorite in the layer. Kaolinite/chlorite is absent from the -60 to +120 mesh of the Rocky Fork till;however, approximately 20% of the kaolinite/chlorite in this layer is finer (Figure 11).

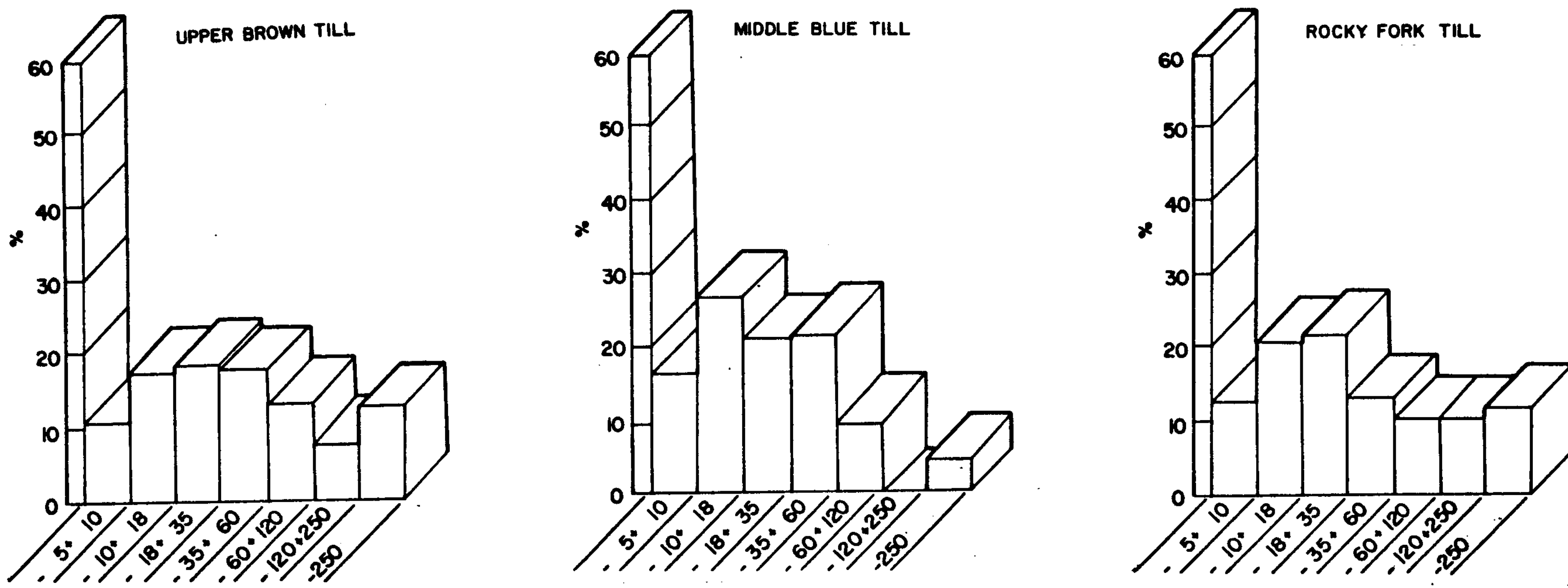

Figure 10. Relative percent abundances of illite in each size fraction of each till layer at Gahanna, Ohio.

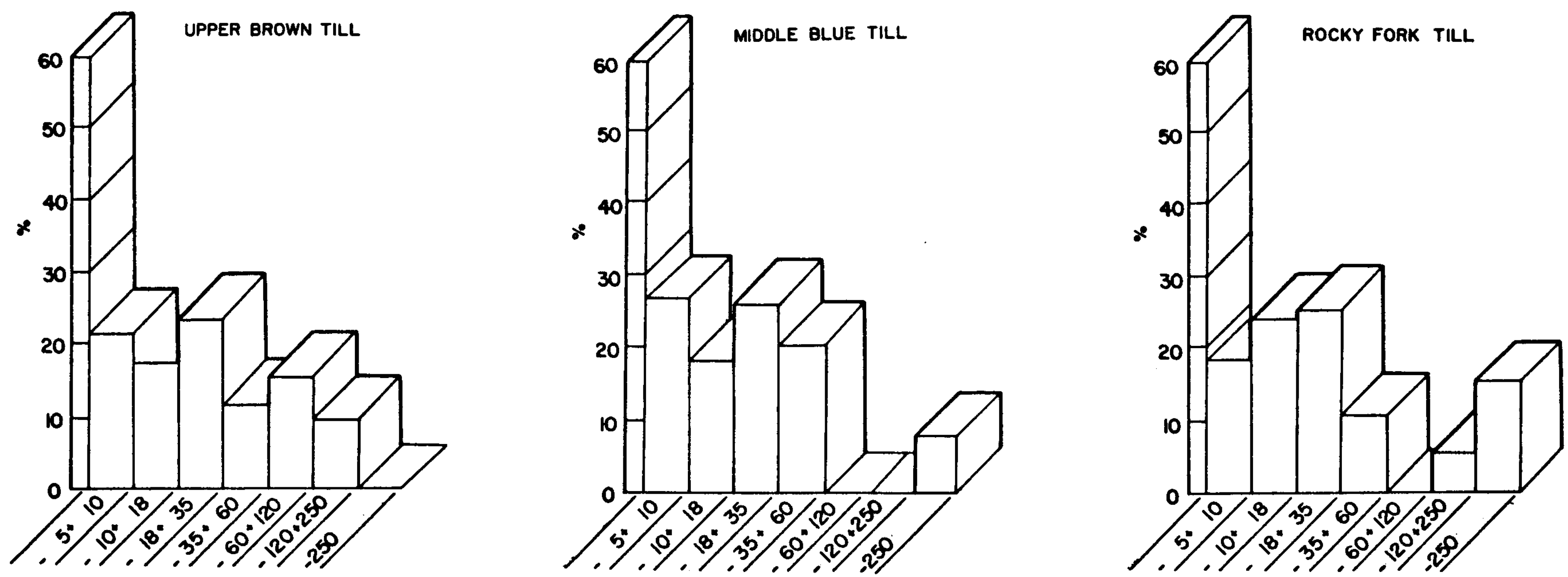

Figure 11. Relative percent abundances of kaolinite/chlorite in each size fraction of each till layer at Gahanna, Ohio.

The histograms illustrating data on the relative distribution of the total quartz in each till layer are shown by mesh size in Figure 12. The Upper Brown till and the Middle Blue till both have between 10% and 20% of their quartz in the -5+10 mesh size fraction. This is a bit more than the amount of quartz found in the -5+10 mesh of the Rocky Fork till. The majority of quartz in each till layer is found in grains -35 mesh. Peak distributions are: 20% Upper Brown quartz -250 mesh, 20% Middle Blue quartz -120+250 mesh, and 23% Rocky Fork quartz -120+250 mesh. Both the Middle Blue and the Rocky Fork exhibit a decrease in quartz in the -250 mesh size fraction with 16% quartz in the Middle Blue and 11% quartz in the Rocky Fork.

Figure 13 illustrates the relative percentages of feldspar grains in each till layer. Both the Upper Brown till and the Middle Blue till exhibit similar trimodal distributions of feldspar. Peaks which occur: Upper Brown, -5+10 mesh (13.5%), -35+60 mesh (17.0%), and -250 mesh (26.4%); Middle Blue, -5+10 mesh (16%), -35+60 mesh (17.0%), and -250 mesh (22.0%). The Rocky Fork till has its greatest amount of feldspar in the -35+60 mesh fraction with only 6.5% -5+10 mesh and 11% -250 mesh.

INTERPRETATION

The Rocky Fork till is the only layer of the three tills in Gahanna that over rode bedrock during transport. The resulting till contains the largest amount of incorporated bedrock. This gives the Rocky Fork till the coarsest composition of the three layers. The Middle Blue till overlies the Lockbourne Outwash. Dilution of parent material by outwash material is one

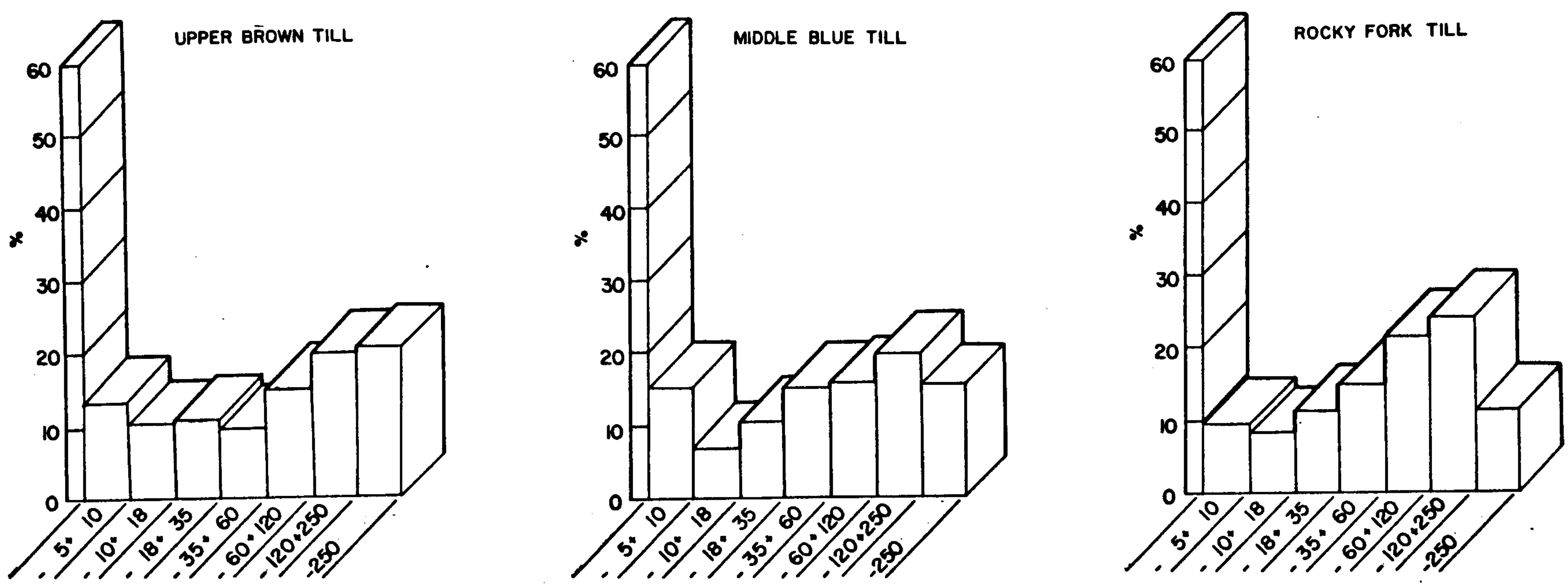

Figure 12. Relative percent abundances of quartz in each size fraction of each till layer at Gahanna, Ohio.

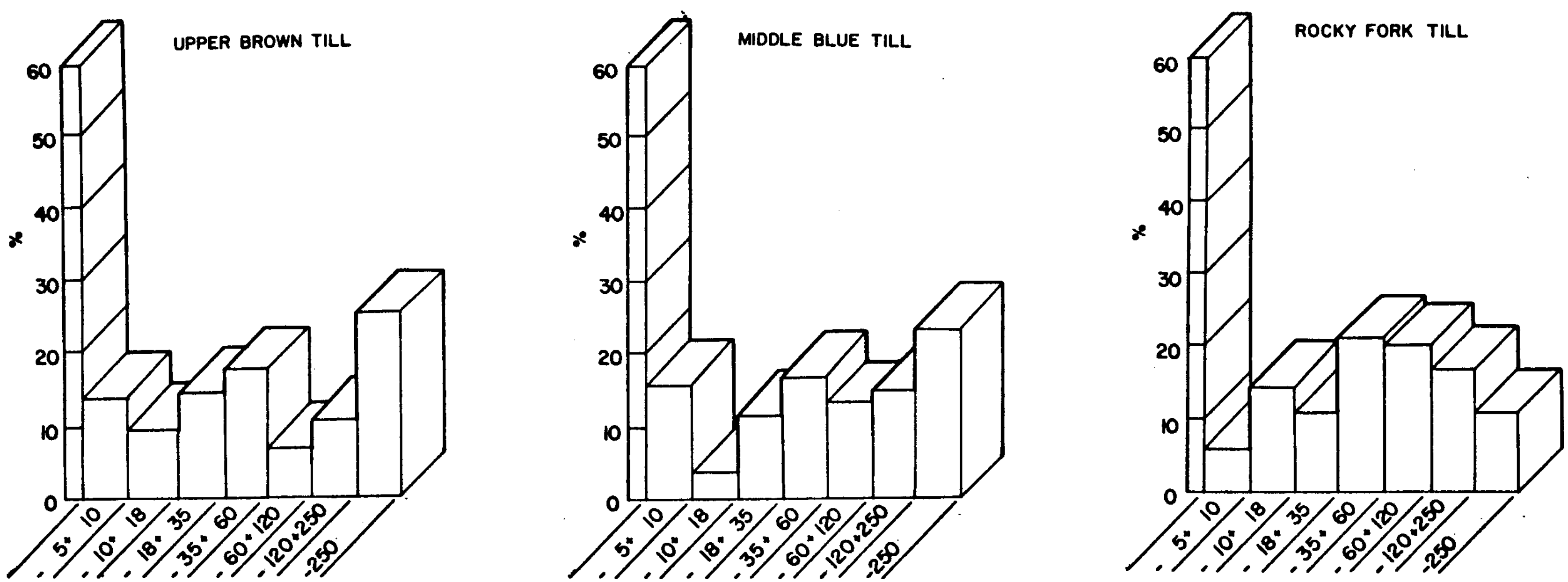

Figure 13. Relative percent abundances of feldspar in each size fraction of each till layer at Gahanna, Ohio.

possible source of coarse material in the layer. The abundance of fine material may result from further comminution of the lower till layer. The Upper Brown till also has an abundance of -250 mesh material. It may be lacustrine clays derived from the Great Lakes or it may be derived from comminution of till material without much bedrock influence. The coarse clasts here are a combination of material from the Canadian Shield and bedrock derived from other tills.

Abundance and concentration of magnetite has never been studied in reference to glacial till. Magnetite in these till layers composes between .05% and .08% of each layer by weight percent. Figure 6 is important for use in locating the greatest concentration of magnetite by size fraction. Information on abundance of magnetite may be used for both regional correlation of tills and for distinguishing till layers. Magnetite is an unstable mineral and can give clues to weathering of tills. Since surface area to volume increases as till clasts become smaller, weathering of tills is first noticed by a decrease in fine grained material. The decrease in concentration of magnetite in the Upper Brown till -60 mesh may indicate a fair amount of weathering. Some weathering is present on magnetite of the Middle Blue while the Rocky Fork exhibits the least alteration of magnetite.

Data on the distribution of carbonate minerals may also be used for regional correlation of tills and for distinguishing different till layers (Dreimanis, 1960). The method of leaching till with 2N HCl does not distinguish between calcite and dolomite. The Upper Brown, Middle Blue, and Rocky Fork tills each consist of between 13% and 18% total carbonates by weight percent. Ohio bedrock is primarily carbonate in composition. This causes the Rocky Fork till which overlies the bedrock to have the greatest amount of carbonates. The local bedrock also influences the coarseness of carbonate minerals. The composition of the upper two till layers is influenced largely by the reworking of till they override. This reworking of carbonate clasts is probably the source of the greater concentration of fine grained carbonates in the -250 size fraction of the Upper Brown and Middle Blue layers.

The relative percent of illite in certain grain size fractions of a particular till may be used for till identification. High illite concentration is characteristic of the middle to late Paleozoic rocks of northern Ohio (Willman, 1963). Illite and chlorite are the predominant clay minerals in non-weathered tills and loesses of the Huron, Erie, and Ontario lobes (Droste, 1956). Illite in the Gahanna tills has a bimodal distribution. Most of the coarse illite originated from shale clasts. This x-ray diffraction peak may have also been influenced by muscovite. The fine illite is the result of glacial comminution and not the result of weathering of feldspar in the till (Faure, personal communication).

Chlorite in the tills of northeastern Ohio is the most unstable of the clay minerals when subjected to weathering (Droste, 1956). Kaolinite/chlorite distribution may be used in till identification and as an indicator of the till weathering profile. Like illite, kaolinite/chlorite concentration in coarse size fractions of the Gahanna till layers does not indicate the occurrence of -5+10 mesh kaolinite/chlorite for example. The lack of -250 mesh chlorite in the Upper Brown till demonstrates that this till layer has been weathered enough to remove fine grained clay minerals such as kaolinite/chlorite. The bimodal distribution in the Middle Blue and Rocky Fork tills reflect the concentration of kaolinite/chlorite derived from certain size clasts and the kaolinite/chlorite composing certain other size clasts.

The concentration of quartz in the finer size fractions of the tills probably indicates presorting of quartz grains and not necessarily glacial comminution. The Berea Sandstone lies to the north of the Gahanna tills and is a very fine grained sandstone, almost siltstone. This could be the source area for most of the quartz in the Rocky Fork till layer. The increase in the -250 mesh quartz in the upper two till layers could have resulted from reworking of the outwash or lower till layers. The coarse quartz was probably derived from a combination of Precambrian gneiss' and shists of the Grenville, Superior, and Southern Provinces.

The grain size distribution of feldspar, by relative percents of the total amount of feldspar present, may be used to characterize glacial tills. Taylor and Faure (1982) determined that most of the feldspar in the Gahanna tills originated from the Canadian Precambrian shield and is a mixture of grains from the Grenville and Superior structural provinces. Bedrock of Ohio consists of sedimentary rocks that contain little feldspar. Their determination of the heterogeneity of the feldspar in the

Upper Brown and Middle Blue till may account in part for the random distribution of feldspar in grain size. The Rocky Fork was found to be all basal till and has a homogeneous composition of feldspar.

SUMMARY

Detailed analysis of grain size distribution of various minerals by weight percent or by relative percents may be used to characterize glacial tills. The distribution and concentration of magnetite, carbonate minerals, illite, kaolinite/chlorite, quartz, and feldspar were used to identify the Upper Brown till, the Middle Blue till, and the Rocky Fork till of Gahanna, Ohio.

The method of extracting magnetite with a hand held magnet to determine grain size distribution and concentration of magnetite in glacial tills may be added to the list of tests used to characterize till layers and correlate them regionally.

Taylor and Faure (1982) indicated very slight alteration of the Gahanna, Ohio tills due to the presence of such unstable components as wood fragments, magnetite, and concentration of marcesite from underlying bedrock. This study furthered the evidence for the lack of weathering in the Gahanna tills. The evidence was acquired through a grain size distribution analysis of magnetite, illite, kaolinite and chlorite. The only till layer which exhibits much weatering is the Upper Brown till. This information seems to coincide with the loosely compacted composition and the oxidation of the Upper Brown till layer.

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